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(54) Focusing apparatus of electron microscope

Fokussierungseinrichtung für Elektronenmikroskop

Dispositif de focalisation pour microscope électronique

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GB-A- 2 011 656

- **JOURNAL OF PHYSICS E. SCIENTIFIC INSTRUMENTS, vol. 20, no. 1, January 1987, pages 67-73, Bristol, GB; T. SUGANUMA: "A novel method for automatic measurement and correction of astigmatism in the SEM"**
- **PATENT ABSTRACTS OF JAPAN, vol. 10, no. 99 (E-396)[2156] 16th April 1986 & JP-A-60 241 633**

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Description

Background of the Invention

The present invention relates to a focusing apparatus of an electron microscope and more particularly to a focusing apparatus of an electron microscope which conducts the correction of astigmatism automatically.

Regarding a usual apparatus of focusing as the preceding stage of correction of astigmatism in the electron microscope wherein the correction of astigmatism is conducted automatically, i.e., a apparatus of determining a circle of least confusion, a description is made in U.S.P. 4,214,163 according to which the circle of least confusion is determined by the following procedures.

(1) An electron beam is made to scan in the direction X on a sample, a signal inversely corresponding to the radius of the electron beam is obtained in each scan, and an exciting current I_1, for a focusing lens whereby the signal is turned to be maximum is determined.

(2) The electron beam is made to scan in the direction Y on the sample, a signal inversely corresponding to the radius of the electron beam is obtained in the same way as the above, and an exciting current I_2 for the focusing lens whereby the signal is turned to be maximum is determined.

(3) The mean value $(I_1 + I_2)/2$ is calculated from aforesaid exciting currents I_1 and I_2 for the focusing lens, and the exciting current for the focusing lens is set at his mean value $(I_1 + I_2)/2$.

By the apparatus described above, the circle of the electron beam focused on the sample becomes the circle of least confusion. The position of this circle of least confusion is equivalent to the position of a focus obtained when the astigmatism is corrected.

In the prior art, as described above, the electron beam is made to scan in each of the directions X and Y, the exciting current for the focusing lens whereby a variation component of a current of a secondary electron or the like generated from the sample on the occasion is turned to be maximum is determined in each scan, and the exciting current for the focusing lens at the time when the circle of least confusion is formed is determined from the mean value of the exciting currents thus determined. The variation component of the secondary electron current is generated by the shape or pattern on the surface of the sample.

According to this apparatus, however, there occurs a problem that the exciting current for the focusing lens corresponding to the circle of least confusion can not be determined exactly when the shape or pattern on the surface of the sample is non-isotropic as in a small part of IC pattern, for example.

Fig. 3 shows the relationship between the focusing lens exciting current applied when an electron beam is made to scan on the sample in each of the directions X and Y with the current varied and an electron beam radius corresponding signal at this time.

By the way, the electron beam radius corresponding signal means a signal inversely corresponding to the radius of the electron beam and is obtained as a variation component of the current of secondary electrons generated from the sample. The more the electron beam is focused on the sample, the bigger the electron beam radius corresponding signal becomes.

This figure shows particularly a case ((b) of the figure 3) wherein no maximum is obtained when scanning is conducted in the direction Y, since the variation component of the shape or pattern on the surface of the sample is small, while the maximum value I_1 is obtained ((a) of the figure 3) when the scanning is conducted in the direction X.

In the case when the shape of the surface on the sample is non-isotropic and therefore a maximum does not appear distinctly, as described above, the aforesaid exciting currents I_1 and I_2 can not be determined exactly according to the prior art, and consequently it is very difficult to exactly determine the exciting current for the focusing lens corresponding to the circle of least confusion. While the apparatus of scanning wherein the electron beam is made to scan in the direction X and Y separately is described in the above-described example, two maxima are obtained as shown in Fig. 5(a) even when the electron beam is made to scan circularly, on condition that the shape of the sample is isotropic, and therefore the exciting current for the focusing lens corresponding to the circle of least confusion can be determined exactly by taking the mean value of said maximum points. When the shape of the sample is non-isotropic, however, the two maxima can not be obtained as shown in Fig. 5(b) so that the exciting current for the focusing lens corresponding to the circle of least confusion can not be determined exactly.

A focusing apparatus which has the features included in the first part of claim 1 is disclosed in J.Phys.E. Sci. Instrum. 20 (1987) pages 67-73. There, auto-focusing is carried out for three different scanning directions to find three focus lens currents, i.e. lens currents each minimising the beam diameter in the corresponding direction. A number of mathematical procedures are necessary to determine a common optimum exciting current from the results obtained in the three scannings.

Summary of'the Invention

An object of the present invention is to furnish a focusing apparatus of an electron microscope which enables the solution of the above-described problem and the exact and simple determination of the exciting current for the focusing lens corresponding to the circle of least confusion.

This object is met by the apparatus defined in claims 1 or 4.

Brief Description of the Drawings

Figure 1 is a simplified block diagram showing the principal structural elements of a scanning electron microscope to which the present invention is applied.

Figures 2(a), 2(b), 2(c) and 2(d) are graphs for illustrating the principle of focusing in the scanning electron microscope to which the present invention is applied.

Figures 3(a), 3(b), 5(a) and 5(b) are graphs showing the relationship betwen a focusing lens exciting current and an electron beam radius corresponding signal.

Figure 4 is a schematic view of tracks of scanning in the case when an electron beam is made to scan in arbitrary directions.

Detailed Description of the Preferred Embodiments

An embodiment of the present invention will be described hereunder by using drawings.

Figure 1 is a simplified block diagram showing the principal structural elements of a scanning electron microscope to which the present invention is applied.

In the figure, numeral 1 denotes an electron beam, which is focused finely on a sample 3 by a focusing lens 2. Numeral 14 denotes a focusing lens driving circuit for driving the focusing lens 2, and it is connected to a control circuit 7 which will be described later.

4 and 5 denote deflecting coils for making the aforesaid electron beam scan in the directions X and Y, respectively, and 10 and 11 deflecting coil exciting circuits for driving said deflecting coils 4 and 5 respectively.

Both of said deflecting coil exciting circuits 10 and 11 are connected to the control circuit 7.

8 and 9 denote X-direction and Y-direction astigmatism correcting coils respectively, and 12 and 13 astigmatism correcting coil exciting circuits for driving said astigmatism correcting coils 8 and 9 respectively.

Both of said astigmatism correcting coil exciting circuits 12 and 13 are connected to the control circuit 7.

Numeral 6 denotes a detector detecting a signal of a secondary electron or the like generated form the sample 3 by the application of the aforesaid electron beam, and the detector is connected to a focusing lens optimum exciting current determining circuit 15.

The focusing lens optimum exciting current determining circuit 15 sets an exciting current for the focusing lens corresponding to a circle of least confusion of the basis of an output signal from the aforesaid detector 6, and outputs a set value to the control circuit 7.

The control circuit 7 controls the aforesaid focusing lens driving circuit 14, the deflecting coil exciting circuits 10 and 11 and the astigmatism correcting coil exciting circuits 12 and 13.

In the scanning electron microscope which has the above-stated construction and to which the present invention is applied, the aforesaid electron beam 1 is made to scan circularly on the sample 3 by varying an exciting current for the deflecting coils 4 and 5. The detector 6 detects an image signal of secondary electrons, a thermoelectrons, absorption electrons or the like generated from the sample 3 and outputs the image signal to the focusing lens optimum exciting current determining circuit 15.

Said focusing lens optimum exciting current determining circuit 15 converts the aforesaid image signal into a signal corresponding to the spot radius of the electron beam 1.

Herein, an integral value of a variation of the image signal generated from the detector 6 is used as the signal corresponding to the spot radius of the aforesaid electron beam 1.

The image signal delivered from the aforesaid detector 6 shows a sharper variation as the thickness of the electron beam 1 in the scanning direction (in the tangential direction in the case of circular scanning) on the sample 3 becomes smaller, and therefore the image signal on the occasion contains a large amount of variation component. This means, as a consequence, that, when the variation component of the aforesaid image signal is taken out as the signal corresponding to spot radius of the electron beam 1 and only a varied part of said variation component is integrated for each one scanning, the thickness of the spot radius of the electron beam 1 in the scanning direction becomes smaller as the integral value obtained by the integration (hereinafter called an electron beam radius corresponding signal) becomes larger.

The aforesaid focusing lens optimum exciting current determining circuit 15 determines the relationship between the intensity of current supplied to the focusing lens driving circuit 14 and the signal corresponding to the electron beam on the occasion, determines a focusing lens exciting current corresponding to the circle of least confusion from this relationship and outputs same to the control circuit 7.

While generating the focusing lens exciting current corresponding to the aforesaid circle of least confusion to the focusing lens driving circuit 14, the control circuit 7 controls the deflecting coil exciting circuits 10, 11 and the astigmatism correcting coil exciting circuits 12, 13.

A method of determining the focusing lens exciting current corresponding to the circle of least confusion by the scanning electron microscope of the present invention will be described in detail hereunder by using Figure 2.

This figure shows the relationship between the integral value of the electron beam radius corresponding signal and an exciting current for the focusing lens driving circuit 14 on the occasion when the electron beam is made to scan circularly on the sample, showing particularly the case when the two maxima do not appear distinctly since the shape of the sample is non-isotropic.

In the case when the two maxima do not appear

distinctly as the above, it is very difficult to determine exactly the exciting current for the focusing lens corresponding to the circle of least confusion, according to the prior art.

Figure 2(a) is a graph for illustrating a focusing operation according to one embodiment of the present invention.

First, the relationship between the electron beam radius corresponding signal obtained from the variation of the secondary electron emitted from the specimen in each circular scan of said electron beam on the specimen and the exciting current for the focusing lens on the occasion, is determined.

For simplification of description, the aforesaid relationship is represented herein as a curve

$$Y = f(I_x).$$

Subsequently, an exciting current I_s for the focusing lens corresponding to the maximum value V_1 of said curve $Y = f(I_x)$ is determined, further electron beam radius corresponding signals $V_3 = f(I_s + \Delta I)$ and $V_2 = f(I_s - \Delta I)$ obtained when an increase and a decrease are made by a certain value ΔI from said exciting current I_s as the center value are determined, and the minimum value of these signals is set as V_0. $V_0 = V_3$ in the present embodiment, since $V_2 > V_3$.

While the electron beam radius corresponding signals V_2 and V_3 are described as determined by making the increase and decrease by the equal amount ΔI from the focusing lens exciting current I_s corresponding to the maximum value V_1, which is set as the center value, values of the increase and decrease are not necessarily equal, but they may be arbitrary values respectively on condition that said exciting current I_s be made to exist within the limits of these increase and decrease.

Successively, the center of gravity G_1 of the region (the hatched part) surrounded by a straight line $Y = V_0$ and the aforesaid curve $Y = f(I_x)$ is determined. The exciting current I_{g1} for the focusing lens corresponding to said position of the center of gravity G_1 is the exciting current corresponding to the circle of least. confusion.

The above-mentioned center of gravity G_1 can be determined by a proper method known publicly (also in other embodiments to be described in the following).

Another embodiment of the present invention will be described hereunder by using Figure 2(b).

After the minimum value V_0 is determined in the same way as in the above-described case of Fig. 2(a), an electron beam radius corresponding signal

$$V_s = (V_1 - V_0)\alpha + V_0$$

is determined from the aforesaid maximum V_1 and the minimum value V_0, and the center of gravity G_2 of the region (the hatched part) surrounded by a straight line $Y = V_s$ and the aforesaid curve $Y = f(I_x)$ is determined. Preferably, the value α is set within the limits of 0.1 to 0.5 and the exciting current I_{g2} for the focusing lens corresponding to the position of said center.of gravity G_2 is the exciting current corresponding to the circle of least confusion.

Still another embodiment of the present invention will be described hereunder by using Figure 2(c).

After the straight line $V_s = (V_1 - V_0)\alpha = V_0$ is determined in the same way as in the above-described figure (b), intersecting points of the straight line $Y = V_s$ and the aforesaid curve $Y = f(I_x)$ are denoted by I_3 and I_4 respectively, and the center of gravity of the region (hatched part) surrounded by a straight line $X = I_3$, a straight line $X = I_4$ and a straight line $Y = V_t$ parallel to the X axis and $0 < V_t < V_s$ is denoted by G_3. The exciting current I_{g3} for the focusing lens corresponding to the position of said center of gravity G_3, thus obtained, may also be used as the exciting current corresponding to the circle of least confusion.

The present embodiment of Fig. 2(c) shows the case when V_t is set to be equal to 0.

Besides, as an approximate value of the aforesaid gravity, the middle point of the aforesaid intersecting points I_3 and I_4 may be taken also for an exciting current I_{g4} for the focusing lens corresponding to the circle of least confusion, as shown in Figure 2(d).

Although the case when the circular scanning is taken as the scanning method of the electron beam is cited in the foregoing description, the present invention is not limited thereto, and an ordinary method of scanning in the directions X and Y, scanning in the shape of a closed loop, or scanning of the electron beam in a number of arbitrary directions as shown in Figure 4, may be adopted as well. The aforesaid curve of the electron beam radius corresponding signal is determined from the mean value of electron beam radius corresponding signals obtained on the occasion, and thereafter the exciting current for the focusing lens corresponding to the circle of least confusion is determined in the same way as in the foregoing embodiments.

In other words, any method of scanning may be adopted, provided that the focusing apparatus of an electron microscope is employed wherein the exciting current for the focusing lens is determined from the position of the center of gravity of an area surrounded by the curve of the electron beam radius corresponding signal corresponding to the exciting current for the focusing lens obtained when the electron beam is made to scan with said exciting current varied, and by a prescribed straight line, or from the intersecting points of the curve and the line.

When the exciting current for the focusing lens corresponding to the circle of least confusion is determined as described above, the control circuit 7 fixes at this exciting current the intensity of current supplied to the focusing lens driving circuit 14 and then executes the so-called correction of astigmatism to further lessen the radius of the aforesaid circle of least confusion.

It is clear that the application of the above-described present invention to the correction of astigmatism enables the exact and simple correction of astigmatism,

compared with the prior-art case.

Moreover, the repetition of the focusing operation of the focusing lens and the correction of astigmatism described above enables the implementation of further exact focusing.

Although only the case when the present invention is applied to the scanning electron microscope is mentioned in the above description, the present invention is not limited thereto, but can be applied also to transmission electron microscope apparatuses, provided that a means to make the electron beam scan in one direction at least is provided.

According to the present invention, as described above, it is possible to furnish the focusing apparatus of an electron microscope which enables the exact and simple determination of the exciting current for the focusing lens corresponding to the circle of least confusion in the stage of the focusing operation conducted before the operation of correction of astigmatism even when the shape of a sample is non-isotropic and when the maximum of the curve of the electron beam radius corresponding signal does not appear distinctly.

Claims

1. A focusing apparatus of an electron microscope which includes

   a focusing lens (2) for focusing the electron beam (1) onto a sample (3),
   deflecting means (4, 5, 10, 11) for scanning the beam (1) in a plurality of directions on the sample (3),
   astigmatism correcting means (8, 9, 12, 13) disposed in the vicinity of the passage of the beam (1),
   detecting means (6) to detect a signal generated from the sample (3) when scanned by the beam (1), and
   determining means (15) to determine the optimum exciting current (I) for the focusing lens (2) at which the spot of the beam (1) on the sample (3) forms a circle of least confusion,

   characterised in that the determining means (15) determines as said optimum exciting current (I) the exciting current (I_g) at the position of the centre of gravity (G) of an area which is confined in a Y-I plane by

   a curve represented by the formula $Y = f(I)$ which is obtained from the output signal of the detecting means (6) and inversely corresponds to the spot radius of the beam (1), and
   a straight line represented by $Y = (V_1 - V_0)\alpha + V_0$, with $0.1 < \alpha < 0.5$, V_0 equalling the smaller one of those two values V_2, V_3 which said curve assumes for $(I_s + \Delta I_p)$ and $(I_s - \Delta I_m)$, I_s being the exciting current resulting in the maximum value (V_1) of said curve, and ΔI_p, ΔI_m being variations from I_s.

2. The apparatus of claim 1, wherein f(I) is obtained from the integrated value of the output signal of the detecting means (6).

3. The apparatus of claim 1 or 2, wherein $\Delta I_p = \Delta I_m$.

4. The apparatus of any preceding claim, modified by

   said straight line being represented by $Y = V_t$, with $V_t < (V_1 - V_0)\alpha + V_0$, and
   said area being further confined by a pair of straight lines represented by $I = I_3$ and $I = I_4$, with I_3, I_4 corresponding to the points of intersection between said curve and a straight line represented by $Y = (V_1 - V_0)\alpha + V_0$

5. The apparatus of claim 4, wherein $V_t = 0$.

6. The apparatus of claim 4 or 5, wherein I_g is approximated as $(I_3 + I_4)/2$, with I_3, I_4 corresponding to the points of intersection between said curve and said straight line.

7. The apparatus of any one of claims 1 to 6, wherein said deflecting means (4, 5, 10, 11) are operable to scan the beam (1) along a circle.

8. The apparatus of any one of claims 1 to 7, wherein said astigmatism correcting means (8, 9, 12, 13) is adapted to be operated after determining the optimum exciting current at the value I_g given by said determining means (15).

Patentansprüche

1. Fokussiereinrichtung für ein Elektronenmikroskop umfassend

   eine Fokussierlinse (2) zum Fokussieren des Elektronenstrahls (1) auf eine Probe (3),
   eine Ablenkeinrichtung (4, 5, 10, 11) zum Abtasten der Probe (3) mit dem Strahl (1) in mehreren Richtungen,
   eine nahe dem Strahlengang (1) angeordnete Astigmatismus-Korrektureinrichtung (8, 9, 12, 13),
   eine Detektoreinrichtung (6) zum Erfassen eines von der Probe (3) beim Abtasten mit dem Strahl (1) erzeugten Signals, und
   eine Bestimmungseinrichtung (15) zur Bestimmung desjenigen optimalen Erregerstroms (I) für die Fokussierlinse (2), bei der der von dem

Strahl (1) auf der Probe (3) gebildete Fleck einen Kreis geringster Zerstreuung bildet,

dadurch **gekennzeichnet,** daß die Bestimmungseinrichtung (15) als optimalen Erregerstrom (I) den Erregerstrom (I_g) an der Stelle des Schwerpunktes (G) einer Fläche bestimmt, die in einer Y-I-Ebene begrenzt wird von

einer durch die Gleichung Y = f(I) gegebenen Kurve, wobei diese Gleichung durch das Ausgangssignal der Detektoreinrichtung (6) gewonnen wird und in umgekehrtem Verhältnis zum Fleckradius des Strahls (1) steht, und
einer durch $Y = (V_1 - V_0)\alpha + V_0$ gegebenen Geraden, wobei $0{,}1 < \alpha < 0{,}5$; V_0 gleich ist dem kleineren derjenigen beiden Werte V_2, V_3, die die Kurve für ($I_s + \Delta I_p$) und ($I_s - \Delta I_m$) annimmt; I_s der beim Maximum (V_1) der besagten Kurve sich einstellende Erregerstrom ist; und ΔI_p, ΔI_m Streuungen von I_s sind.

2. Einrichtung nach Anspruch 1, wobei f(I) aus dem Integral des Ausgangssignals der Detektoreinrichtung (6) gewonnen ist.

3. Einrichtung nach Anspruch 1 oder 2, wobei $\Delta I_p = \Delta I_m$.

4. Einrichtung nach einem der vorhergehenden Ansprüche mit der Abänderung, daß

die Gerade durch $Y = V_t$ gegeben ist, wobei $V_t < (V_1 - V_0) + V_0$, und
die Fläche ferner von einem durch $I = I_3$ und $I = I_4$ gegebenen Geradenpaar begrenzt ist, wobei I_3, I_4 den Schnittpunkten zwischen der besagten Kurve und einer durch $Y = (V_1 - V_0)\alpha + V_0$ wiedergegebenen Geraden entsprechen.

5. Einrichtung nach Anspruch 4, wobei $V_t = 0$.

6. Einrichtung nach Anspruch 4 oder 5, wobei I_g durch $(I_3 + I_4)/2$ angenähert ist und wobei I_3, I_4 den Schnittpunkten zwischen der besagten Kurve und der besagten Geraden entsprechen.

7. Einrichtung nach einem der Ansprüche 1 bis 6, wobei die Ablenkeinrichtung (4, 5, 10, 11) so betätigbar ist, daß sie den Strahl (1) längs eines Kreises tastet.

8. Einrichtung nach einem der Ansprüche 1 bis 7, wobei die Astigmatismus-Korrektureinrichtung (8, 9, 12, 13) nach Bestimmung des optimalen Erregerstroms bei dem durch die Bestimmungseinrichtung (15) gegebenen Wert I_g betätigbar ist.

Revendications

1. Dispositif de mise au point d'un microscope électronique, qui comprend

une lentille de mise au point (2) pour focaliser un faisceau d'électrons (1) sur un échantillon (3),
des moyens de déviation (4,5,10,11) pour amener le faisceau (1) à balayer l'échantillon (3) dans plusieurs directions, des moyens de correction d'astigmatisme (8,9,12, 13) disposés au voisinage du passage du faisceau (1),
des moyens de détection (6) pour détecter un signal produit par l'échantillon (3) lorsqu'il est balayé par le faisceau (1), et
des moyens de détermination (15) pour déterminer le courant d'excitation optimum (I) pour la lentille de mise au point (2), avec lequel le spot du faisceau (1) pour l'échantillon (3) forme un cercle de confusion minimale,

caractérisé en ce que les moyens de détermination (15) déterminent, en tant que courant d'excitation optimum (I), le courant d'excitation (Ig) dans la position du centre de gravité (G) d'une zone, qui est délimitée dans un plan (Y-I) par

une courbe représentée par la formule Y = f(I), qui est obtenue à partir du signal de sortie des moyens de détection (6) et correspond inversement au rayon du spot du faisceau (1), et
une droite représentée par $Y = (V1-V0)\alpha + V0$, avec $0{,}1 < \alpha < 0{,}5$, V0 étant égale à la plus petite des deux valeurs V2, V3, que la courbe prend pour (Is + ΔIp) et (Is - ΔIm), Is étant le courant d'excitation fournissant la valeur maximale (V1) de ladite courbe et ΔIp, ΔIm étant des variations de Is.

2. Dispositif selon la revendication 1, dans lequel f(I) est obtenu à partir de la valeur intégrée du signal de sortie des moyens de détection (6).

3. Dispositif selon la revendication 1 ou 2, dans lequel on a ΔIp = ΔIm.

4. Dispositif selon l'une quelconque des revendications précédentes, modifié en ce que

ladite droite est représentée par Y = Vt, avec $Vt < (V1 - V0)\alpha + V0$, et
ladite surface étant en outre délimitée par un couple de droites représentées par I = I3 et I = I4, I3, I4 correspondant aux points d'intersection entre ladite courbe et une droite représentée par $Y = (V1-V0)\alpha + V0$.

5. Dispositif selon la revendication 4, dans lequel on a Vt = 0.

6. Dispositif selon la revendication 4 ou 5, dans lequel Ig est approximé par (I3 + I4)/2, I3, I4 correspondant aux points d'intersection entre ladite courbe et ladite droite.

7. Dispositif selon l'une quelconque des revendications 1 à 6, dans lequel lesdits moyens de déviation (4,5,10,11) peuvent agir de manière à amener le faisceau (1) à exécuter un balayage le long d'un cercle.

8. Dispositif selon l'une quelconque des revendications 1 à 7, dans lequel lesdits moyens de correction d'astigmatisme (8,9,12,13) sont adaptés pour fonctionner après détermination du courant d'excitation optimum à la valeur Ig définie par lesdits moyens de détermination (15).

FIG. 1

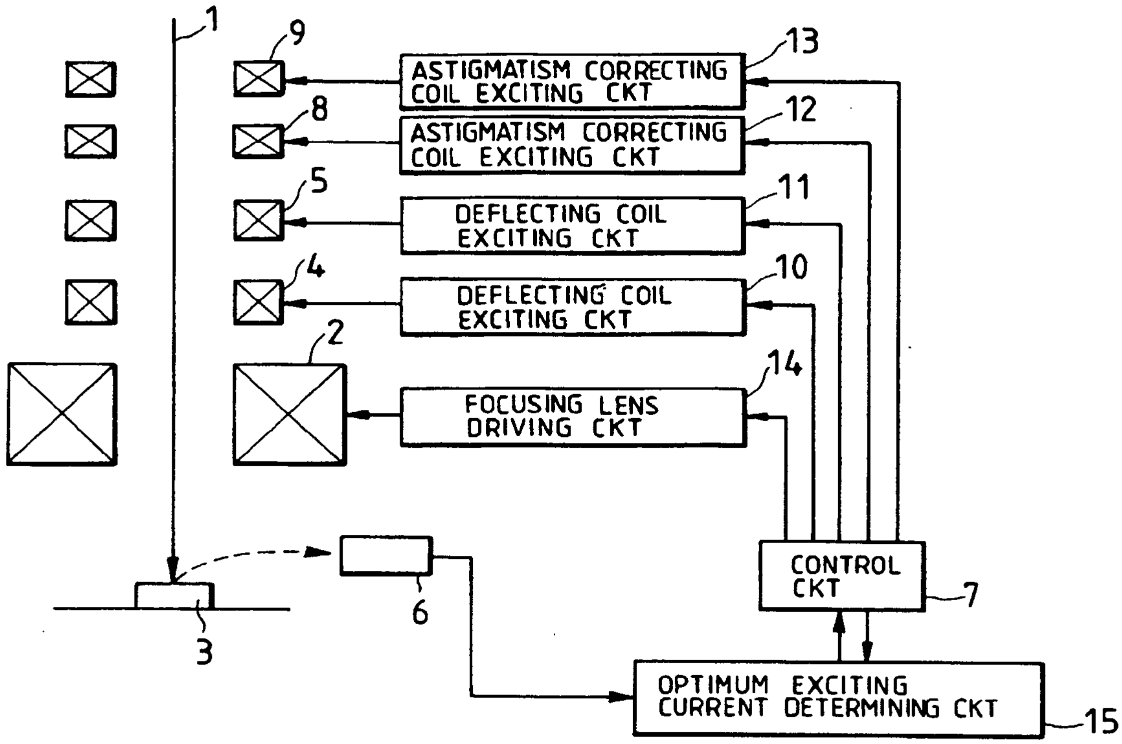

1
9
8
5
4
2
ASTIGMATISM CORRECTING COIL EXCITING CKT
13
ASTIGMATISM CORRECTING COIL EXCITING CKT
12
DEFLECTING COIL EXCITING CKT
11
DEFLECTING COIL EXCITING CKT
10
FOCUSING LENS DRIVING CKT
14
CONTROL CKT
7
6
3
OPTIMUM EXCITING CURRENT DETERMINING CKT
15

FIG. 4

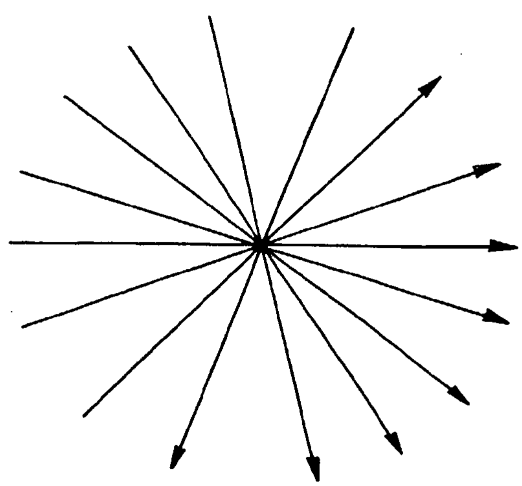


FIG. 2(a)

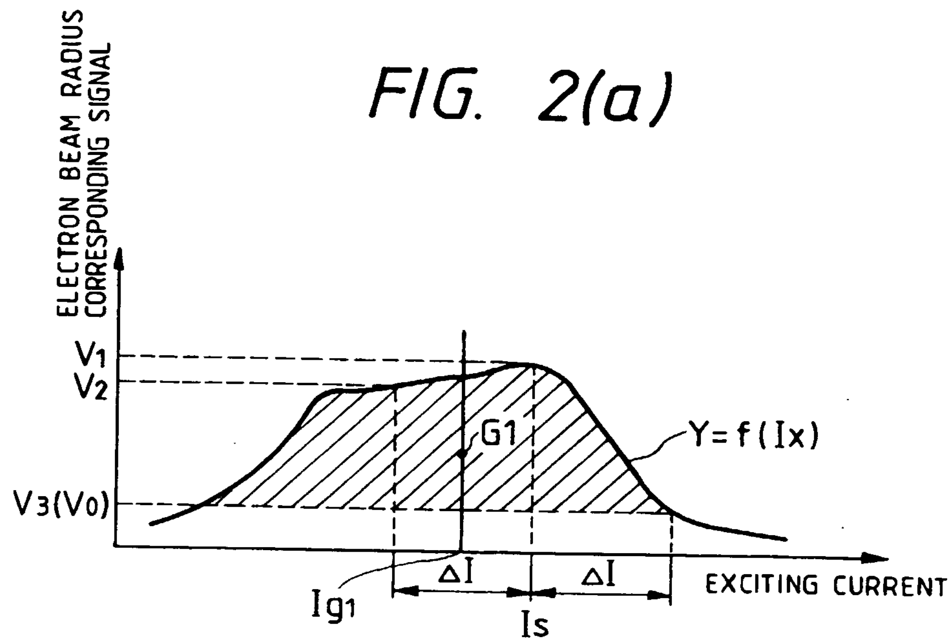

ELECTRON BEAM RADIUS
CORRESPONDING SIGNAL
V1
V2
G1
Y= f (Ix)
V3(V0)
ΔI
ΔI
EXCITING CURRENT
Ig1
Is

FIG. 2(b)

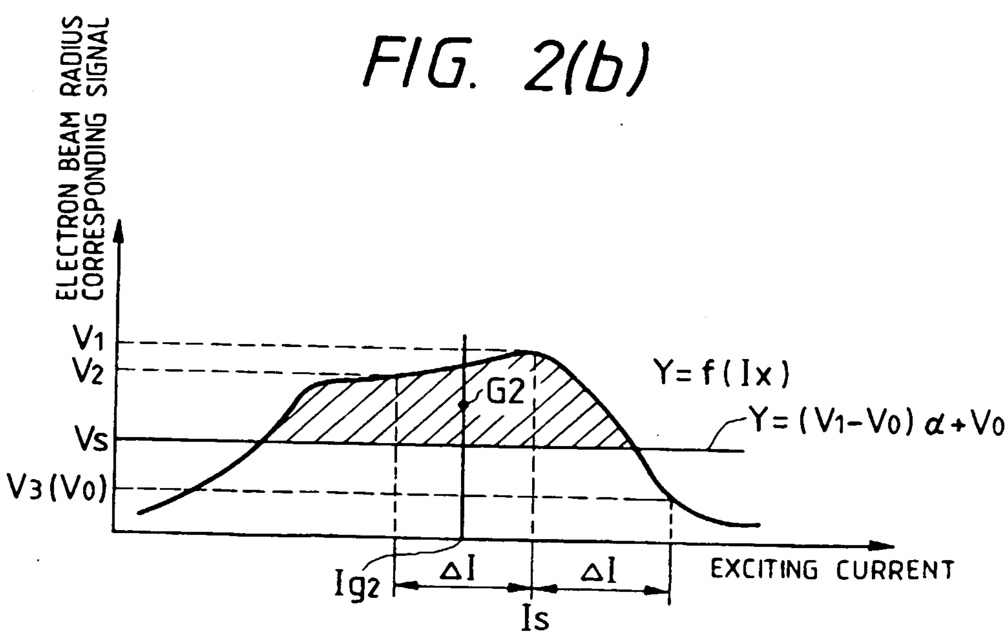

ELECTRON BEAM RADIUS
CORRESPONDING SIGNAL
V1
V2
G2
Y= f (Ix)
Vs
Y= (V1-V0) α+V0
V3 (V0)
Ig2
ΔI
ΔI
EXCITING CURRENT
Is

FIG. 2(c)

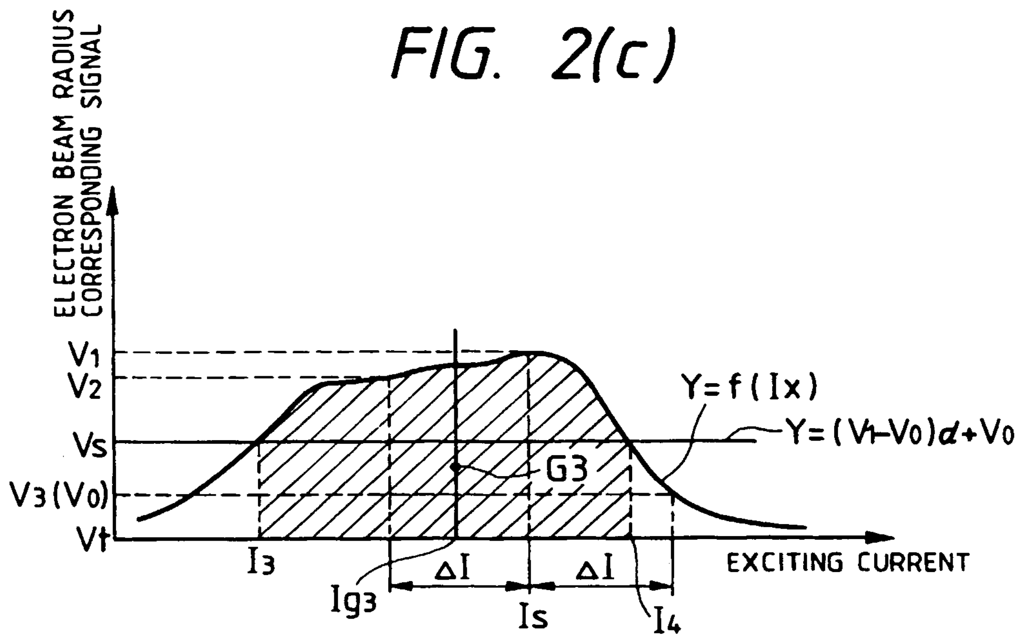

ELECTRON BEAM RADIUS CORRESPONDING SIGNAL
V1
V2
Vs
V3 (V0)
Vt
Y= f (Ix)
Y= (V1-V0)α+V0
G3
I3
Ig3
ΔI
ΔI
Is
I4
EXCITING CURRENT

FIG. 2(d)

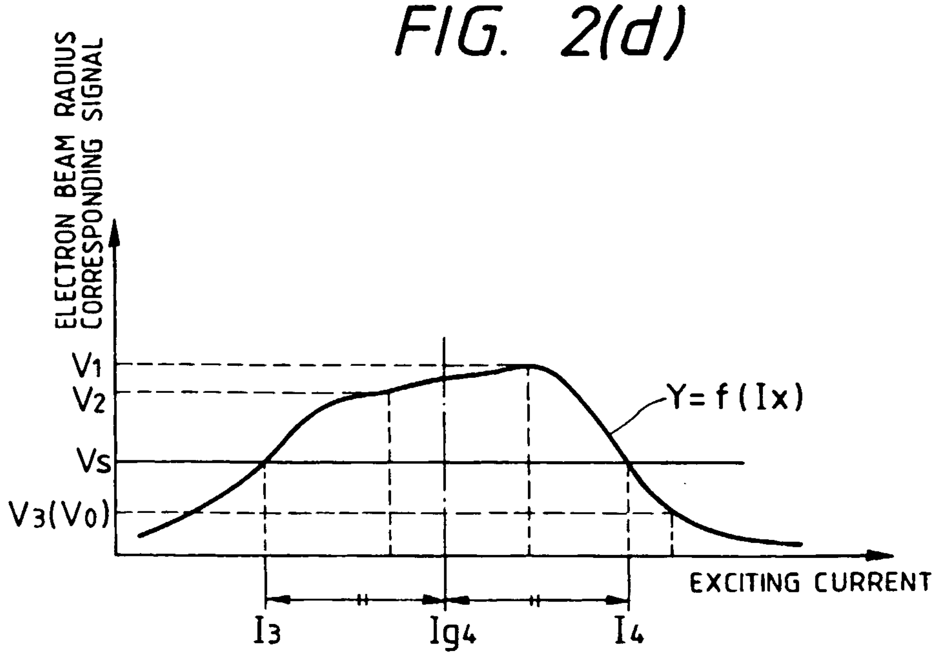

ELECTRON BEAM RADIUS CORRESPONDING SIGNAL
V1
V2
Vs
V3(V0)
Y= f (Ix)
EXCITING CURRENT
I3
Ig4
I4

FIG. 3(a)

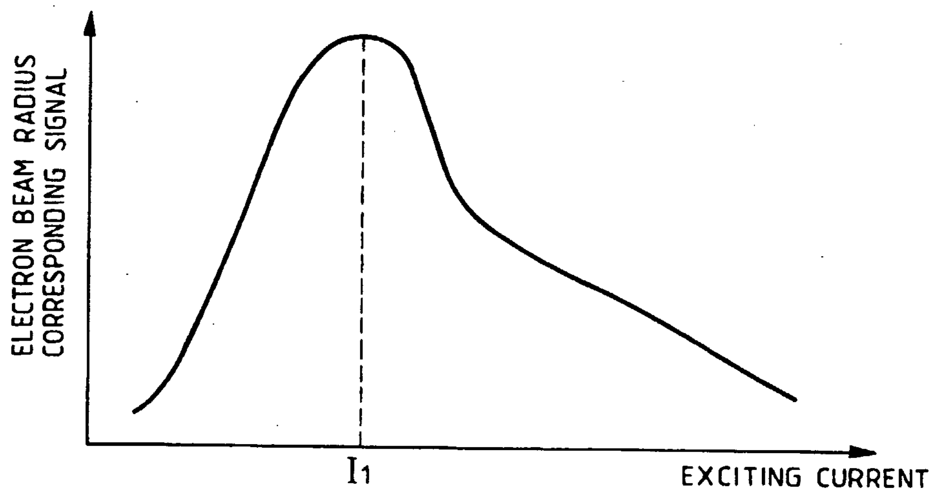

ELECTRON BEAM RADIUS
CORRESPONDING SIGNAL
I1
EXCITING CURRENT

FIG. 3(b)

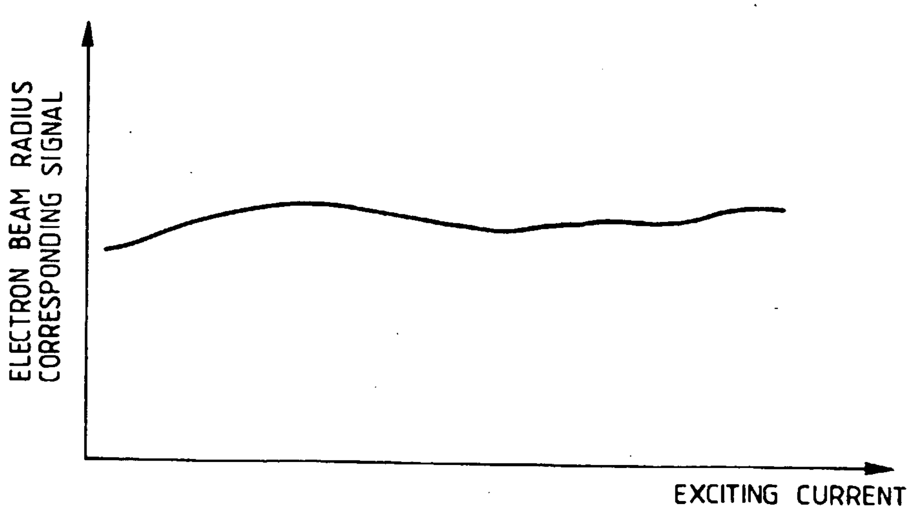

ELECTRON BEAM RADIUS
CORRESPONDING SIGNAL
EXCITING CURRENT

FIG. 5(a)

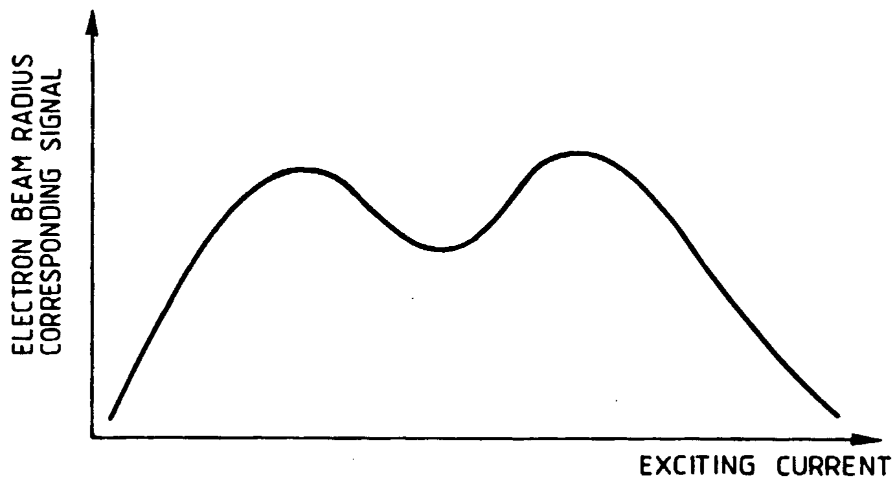
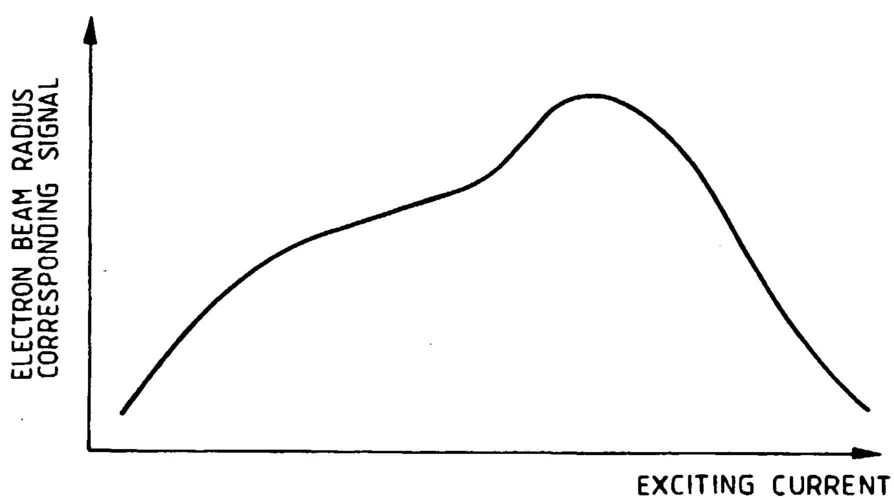

ELECTRON BEAM RADIUS
CORRESPONDING SIGNAL
EXCITING CURRENT

FIG. 5(b)


ELECTRON BEAM RADIUS
CORRESPONDING SIGNAL
EXCITING CURRENT